

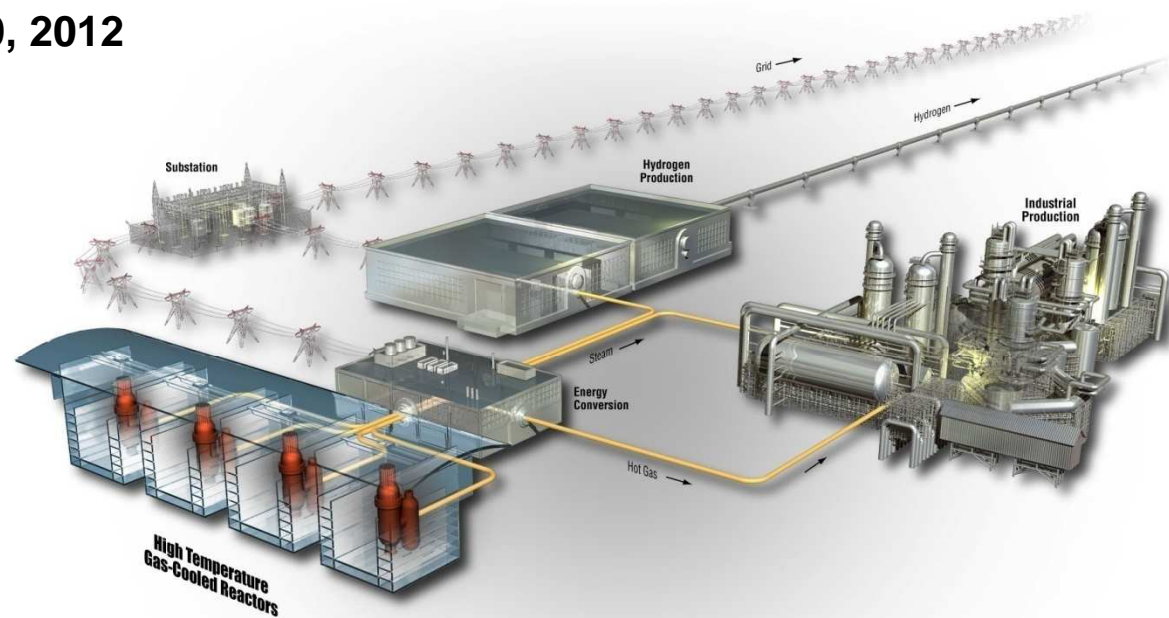
# ***Next Generation Nuclear Plant***

## ***Risk-Informed Performance-Based Licensing Approach***

### ***Responses to LBE Actions***

July 10, 2012

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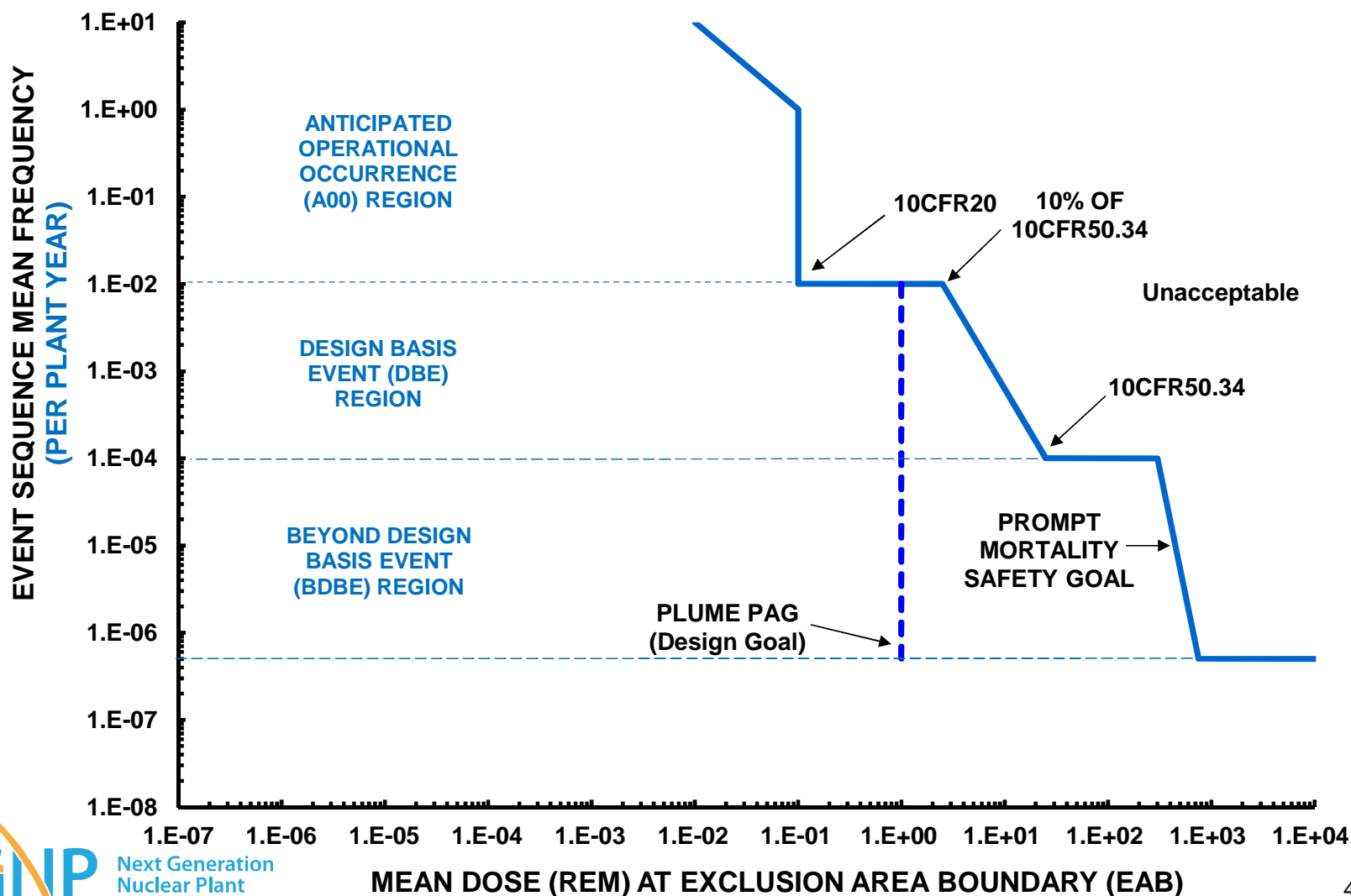
## ***Agreements from May 16<sup>th</sup> Meeting***

- The likelihood of an event is defined by the event sequence frequency, rather than the initiating event frequency
- Agreement on categorizing events on a per plant-year basis, rather than on a per reactor-year basis
- Agreement on use of realistic approach for evaluating compliance to Part 20 for FSAR Chapter 11 routine operations (AOOs)

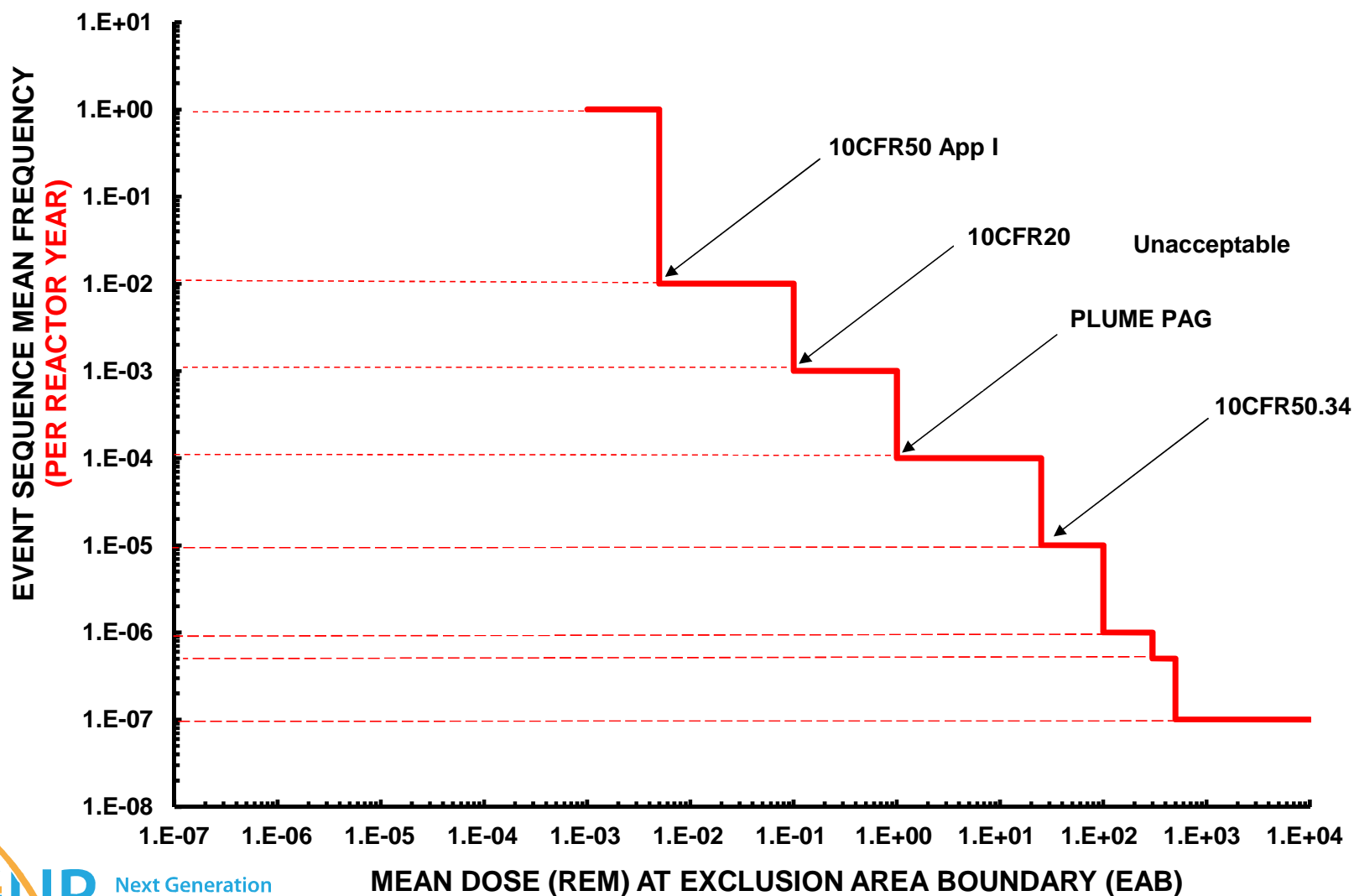
## ***Actions from May 16<sup>th</sup> Meeting***

- **Action** - NGNP should compare at a future meeting its F-C curve to that of NUREG-1860 by adding another ordinate for reactor-year frequency and overlaying the two curves. A discussion should be provided on whether or not the NGNP curve's anchor points correspond to those on the NUREG-1860 curve. NGNP should discuss what the differences mean and what the NGNP curve captures differently from that depicted in NUREG-1860.
- **Response** – Next slides

## NGNP Placement of TLRC on F-C Curve Utilized for One or More Reactor Modules in the Plant



# NUREG-1860 F-C Curve for One Reactor



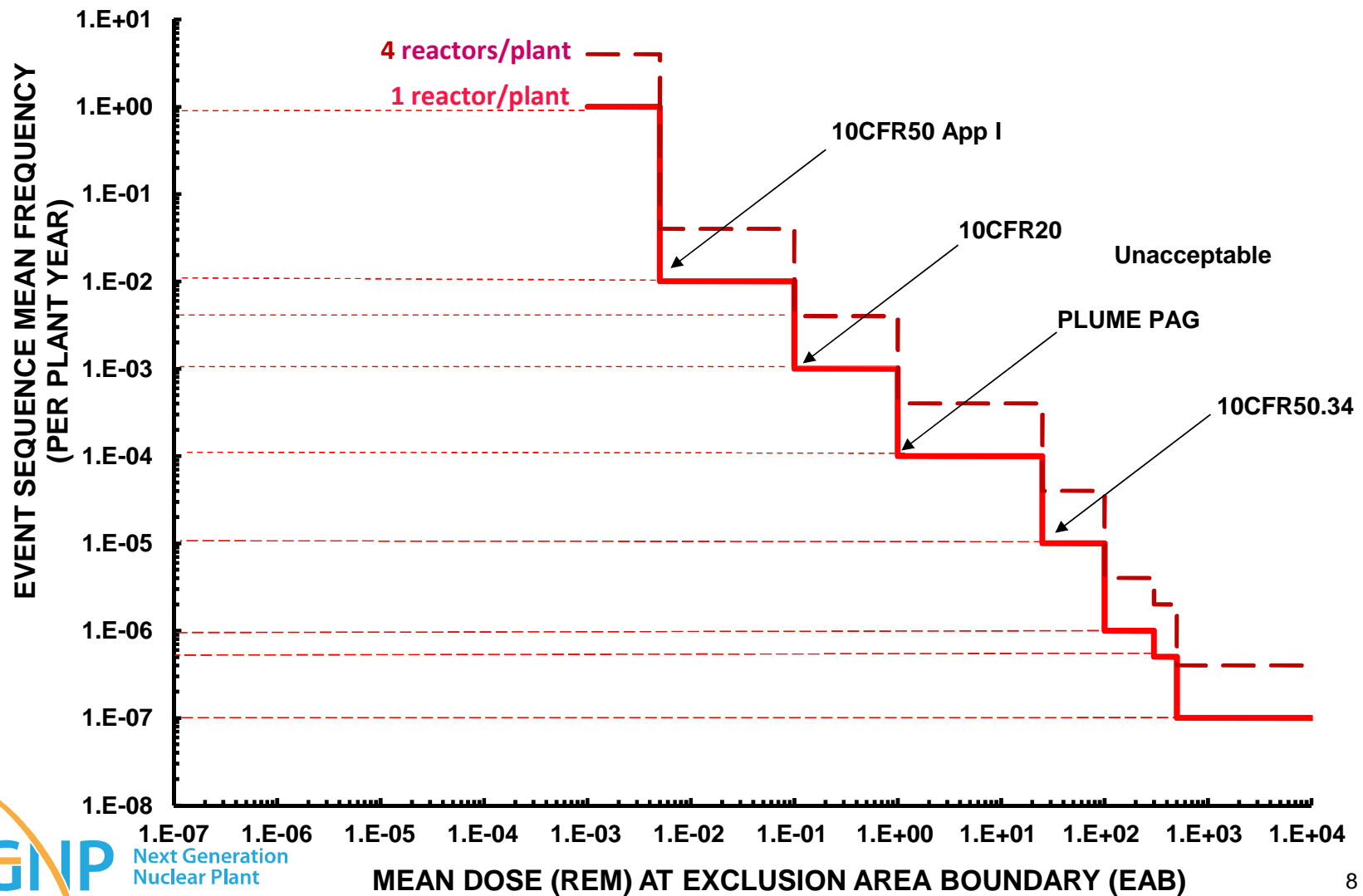
## ***NUREG-1860 F-C Curve Has More Anchor Points and Regions Than NGNP***

<b>Anchor Point</b>	<b>NGNP TLRC</b>	<b>NUREG 1860</b>	<b>Notes</b>
10CFR50 App I (5 mrem)		Yes	ALARA goal
<b>10CFR20 (100 mrem)</b>	Yes	Yes	<b>Agree on need for dose on F-C curve</b>
EPA PAG (1 rem)	Yes*	Yes	Applies to all DBEs and BDBEs *Design goal at EAB for NGNP
<b>10CFR50.34 (25 rem)</b>	Yes	Yes	<b>Agree on need for dose on F-C curve</b>
100 rem		Yes	Regulatory basis unclear
<b>Prompt QHO (300 rem)</b>	Yes	Yes	<b>Agree on need for dose on F-C curve</b>
500 rem		Yes	Regulatory basis unclear
<b>Prompt QHO (750 rem)</b>	Yes		<b>Needs to be on F-C curve</b>

## ***NGNP and NUREG-1860 F-C Curve Frequencies Not in Same “Units”***

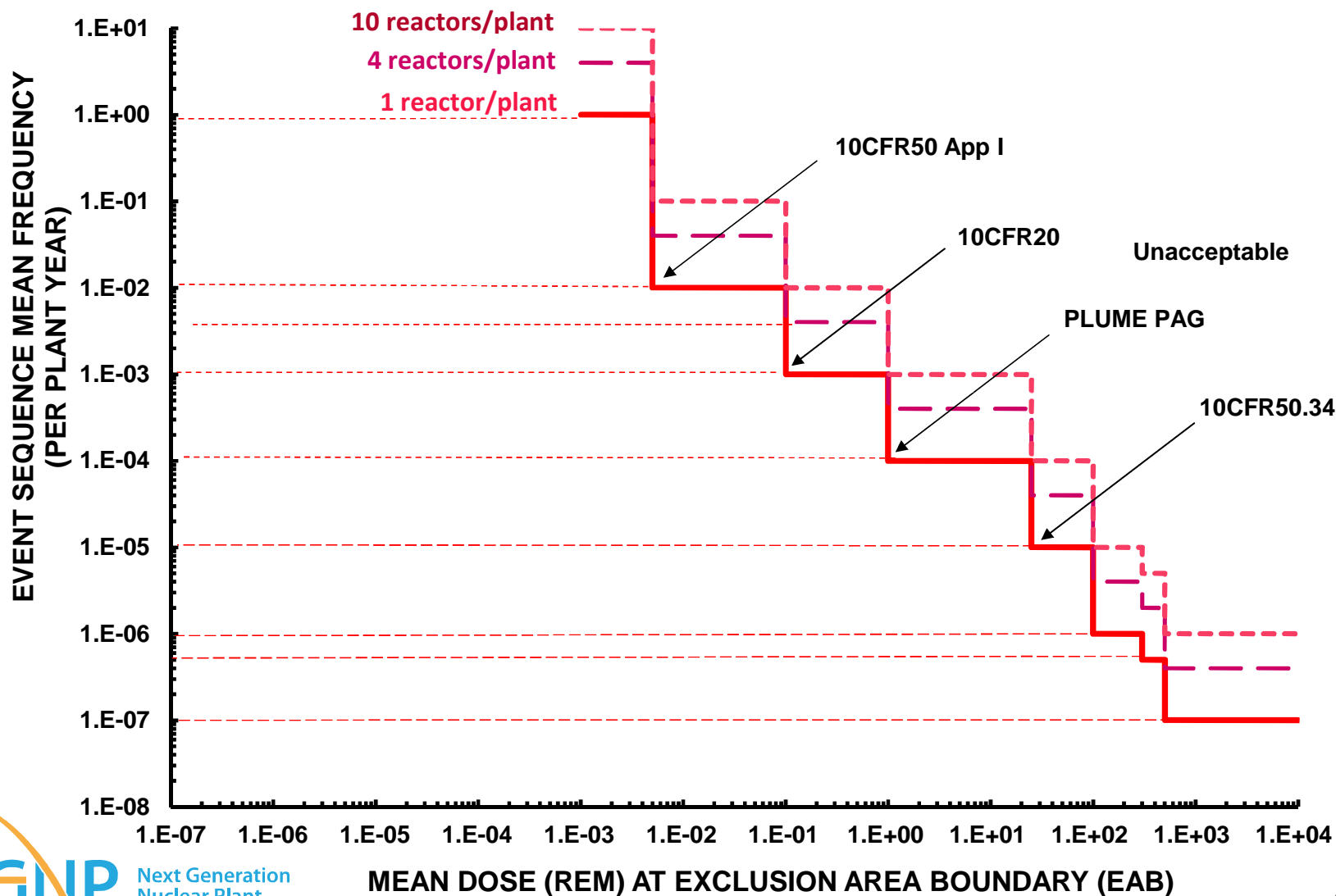
<b>Anchor Point</b>	<b>NGNP TLRC</b>	<b>NUREG 1860</b>	<b>Notes</b>
10CFR50 App I (5 mrem)	-	$10^{-2}/\text{r-yr}$	ALARA goal
10CFR20 (100 mrem)	$10^{-2}/\text{pl-yr}$	$10^{-3}/\text{r-yr}$	Agree on need for dose on F-C curve
EPA PAG (1 rem)	$10^{-2}/\text{pl-yr}$ to $5 \times 10^{-7}/\text{pl-yr}^*$	$10^{-4}/\text{r-yr}$	Applies to all DBEs and BDBEs *Design goal at EAB for NGNP
10CFR50.34 (25 rem)	$10^{-4}/\text{pl-yr}$	$10^{-5}/\text{r-yr}$	Agree on need for dose on F-C curve
<b>100 rem</b>	-	$10^{-6}/\text{r-yr}$	<b>100 rem at NUREG-1860 frequency Is more restrictive than QHO risk</b>
<b>Prompt QHO (300 rem)</b>	$10^{-4}/\text{pl-yr}$	$5 \times 10^{-7}/\text{r-yr}$	Agree on need for dose on F-C curve <b>300 rem at NUREG-1860 frequency Is more restrictive than QHO risk</b>
<b>500 rem</b>	-	$10^{-7}/\text{r-yr}$	<b>500 rem at NUREG-1860 frequency Is more restrictive than QHO risk</b>
Prompt QHO (750 rem)	$5 \times 10^{-7}/\text{pl-yr}$	-	Needs to be on F-C curve

## Frequency of an Event at the Plant Increases with Number of Reactor Modules in a Plant

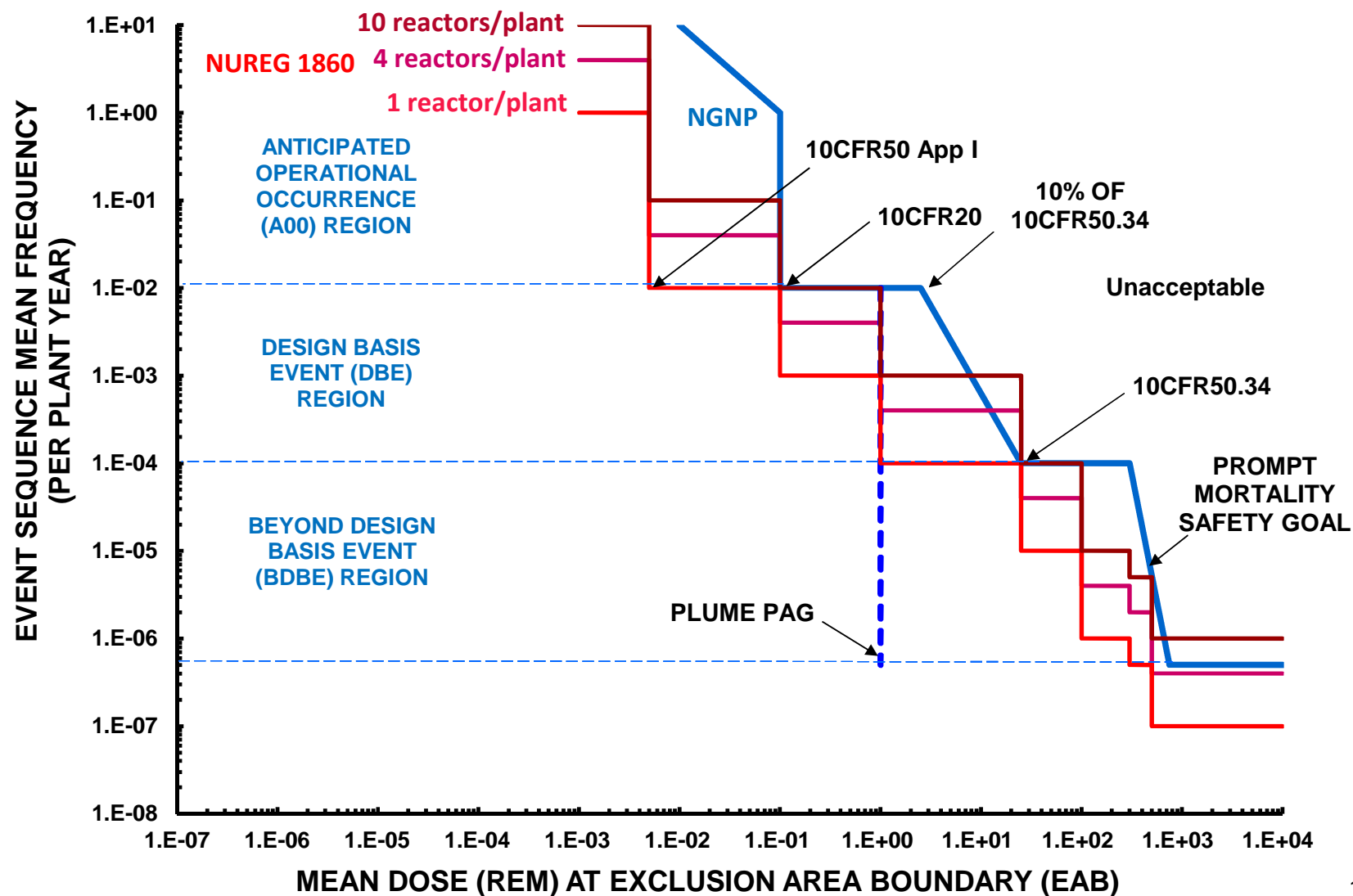




## NUREG-1860 F-C Curve for 1, 4, and 10 Reactors Per Plant



# Comparison of NGNP TLRC with NUREG-1860



## Comparison of 4-Reactor F-C Anchor Point Frequencies

Anchor Point	NGNP TLRC	NUREG 1860 (4 reactors)	Notes
10CFR50 App I (5 mrem)	-	$4 \times 10^{-2}/\text{pl-yr}$	ALARA goal
10CFR20 (100 mrem)	$10^{-2}/\text{pl-yr}$	$4 \times 10^{-3}/\text{pl-yr}$	Agree on need for dose on F-C curve
EPA PAG (1 rem)	$10^{-2}/\text{pl-yr}$ to $5 \times 10^{-7}/\text{pl-yr}^*$	$4 \times 10^{-4}/\text{pl-yr}$	Applies to all DBEs and BDBEs *Design goal at EAB for NNGP
10CFR50.34 (25 rem)	$10^{-4}/\text{pl-yr}$	$4 \times 10^{-5}/\text{pl-yr}$	Agree on need for dose on F-C curve
<b>100 rem</b>	-	$4 \times 10^{-6}/\text{pl-yr}$	<b>100 rem at that frequency Is more restrictive than QHO risk</b>
<b>QHO (300 rem)</b>	$10^{-4}/\text{pl-yr}$	$2 \times 10^{-6}/\text{pl-yr}$	Needs to be on F-C curve <b>300 rem at that frequency Is more restrictive than QHO risk</b>
<b>500 rem</b>	-	$4 \times 10^{-7}/\text{pl-yr}$	<b>500 rem at that frequency Is more restrictive than QHO risk</b>
QHOS (750 rem)	$5 \times 10^{-7}/\text{pl-yr}$	-	Needs to be on F-C curve

## ***Observations from Comparison of NUREG-1860 Anchor Points and FC Curve with NGNP***

- Major difference is frequency metric on a per reactor year vs. per plant year basis
- 10CFR20 is the higher plant level requirement at the EAB rather than 10CFR50 Appendix I
- Three regions have precedent in current practice (e.g., SAR Chapters 11, 15 and 19)
- NUREG-1860 BDBE F-C steps do not correspond to QHO
- NUREG-1860 is more restrictive than the NGNP curve; but becomes less restrictive as more modules are included in the plant design

## ***Actions from May 16<sup>th</sup> Meeting*** *(continued)*

- **Action** - NGNP will plot the staff proposed curve (in RAI-37) against the NGNP curve.
- **Response** – Next slides

## RAI LBE-37

Describe what effect, if any, a revision to frequency-consequence curve would have on the likely classification of equipment, related special treatment requirements, and overall design of facility. Assume the following definition of an alternate F-C curve:

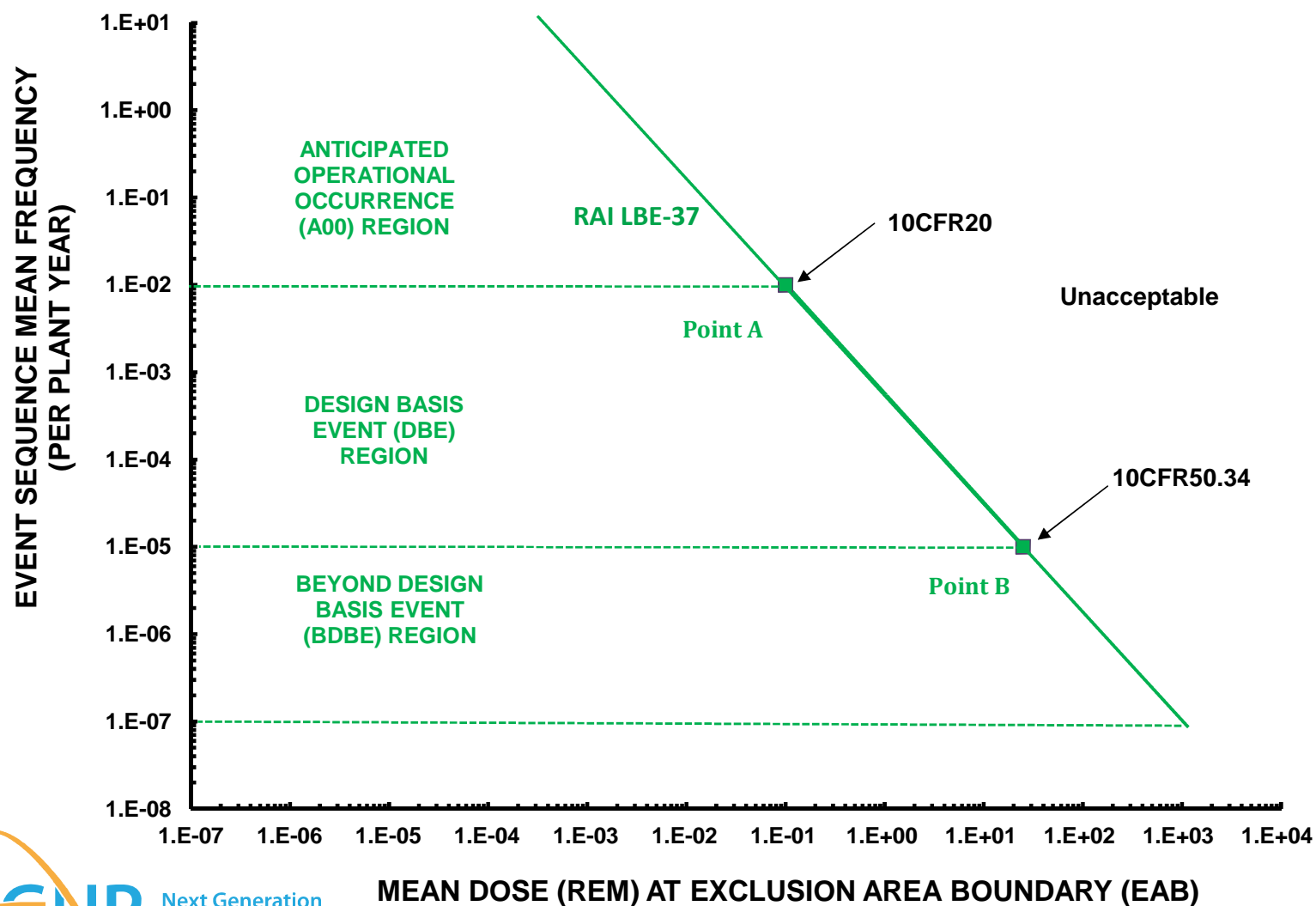
- AOO Region Frequency  $>1\text{E}-2$  (point A)  
Dose = 100mrem
- DBE/DBA Region Frequency  $<1\text{E}-2$  and  $>1\text{E}-5$  (point B)  
Dose = 25 Rem
- BDBE Region Frequency  $<1\text{E}-5$  and  $>1\text{E}-7$   
Dose as defined by line

Boundary line between acceptable and unacceptable regions would be straight line connecting points A and B (continuous through AOO and BDBE regions, i.e., allowable dose approaching 0 as frequency increases).

Handling of site-integrated risk versus unit risk remains an outstanding policy issue, so your response should also discuss the sensitivity of the design to use of curve for events affecting multiple units.

Above F-C graph does not represent an official NRC position. It was developed at staff level for purpose of gaining an understanding of design sensitivities to graph.

## Curve from RAI LBE-37

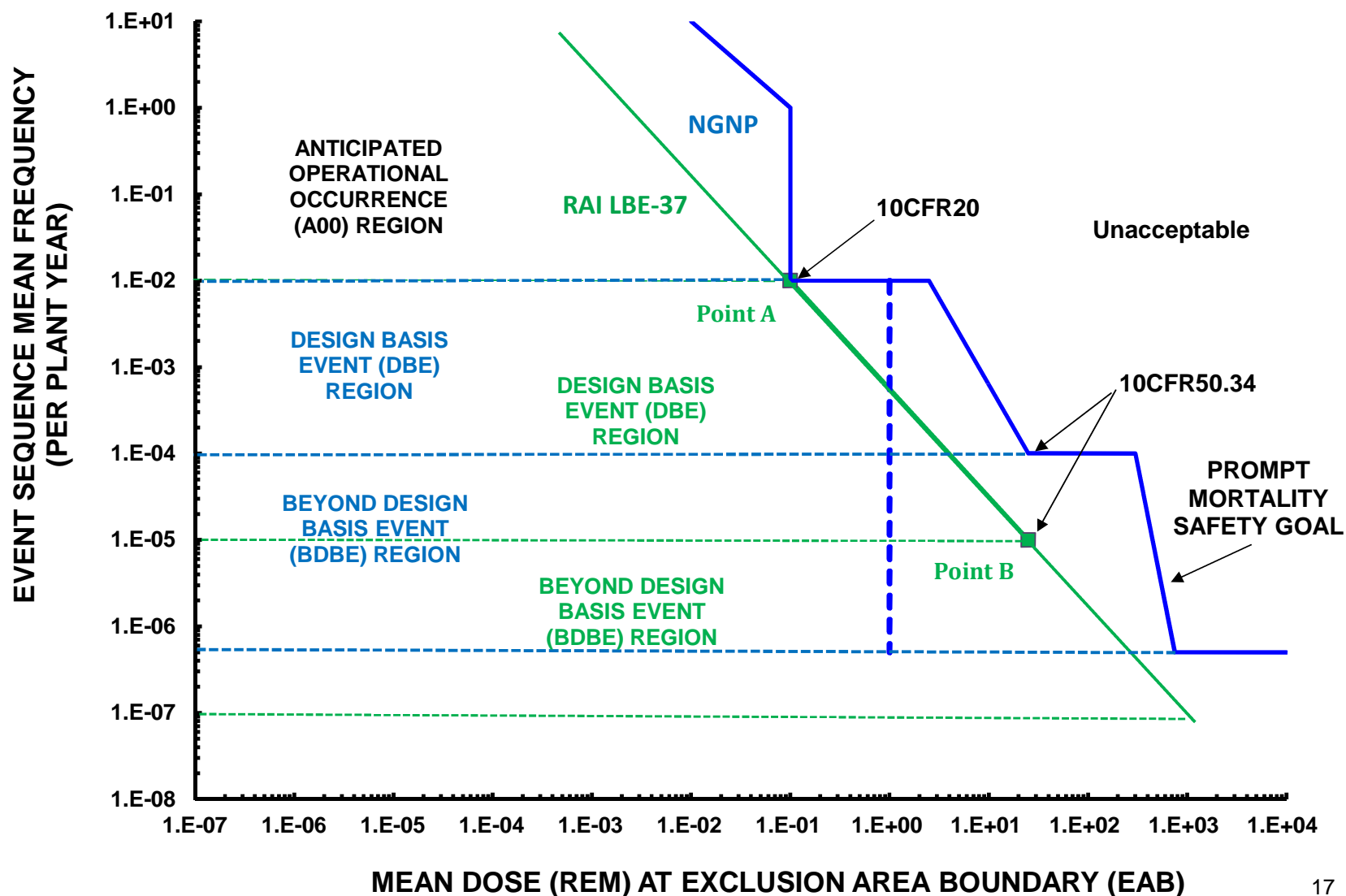


## ***RAI LBE-37 Anchor Points Are More in Agreement with NGNP than NUREG-1860***

<b>Anchor Point</b>	<b>NGNP TLRC</b>	<b>RAI LBE-37</b>	<b>Notes</b>
<b>10CFR20 (100 mrem)</b>	<b>Yes</b>	<b>Yes</b>	<b>Agree on need for dose on F-C curve</b>
<b>10CFR50.34 (25 rem)</b>	<b>Yes</b>	<b>Yes</b>	<b>Agree on need for dose on F-C curve</b>
<b>QHO (300 rem)</b>	<b>Yes</b>	<b>-</b>	<b>Needs to be on F-C curve</b>
<b>QHOs (750 rem)</b>	<b>Yes</b>	<b>-</b>	<b>Needs to be on F-C curve</b>



# Comparison of NGNP and RAI LBE-37 F-C Curves



## ***RAI F-C Curve Has Larger DBE Region and Inconsistent with Prompt QHO***

Anchor Point	NGNP TLRC	RAI LBE-37	Notes
<b>10CFR20</b> (100 mrem)	$10^{-2}/\text{pl-yr}$	$10^{-2}/\text{pl-yr}$	Agree on need for dose on F-C curve <b>Same AOO region term</b> <b>Same lower frequency</b> <b>Need agreement on curve</b>
<b>10CFR50.34</b> (25 rem)	$10^{-4}/\text{pl-yr}$	$10^{-5}/\text{pl-yr}$	Agree on need for dose on F-C curve <b>Same DBE term</b> <b>Need agreement on lower frequency</b> <b>Need agreement on curve</b>
<b>QHO</b> (300 rem)	$10^{-4}/\text{pl-yr}$	-	<b>RAI curve needs consistency with QHO</b>
<b>QHOs</b> (750 rem)	$5 \times 10^{-7}/\text{pl-yr}$	-	<b>RAI curve needs consistency with QHO</b>

## ***Observations from Comparison of RAI Anchor Points and FC Curve with NGNP***

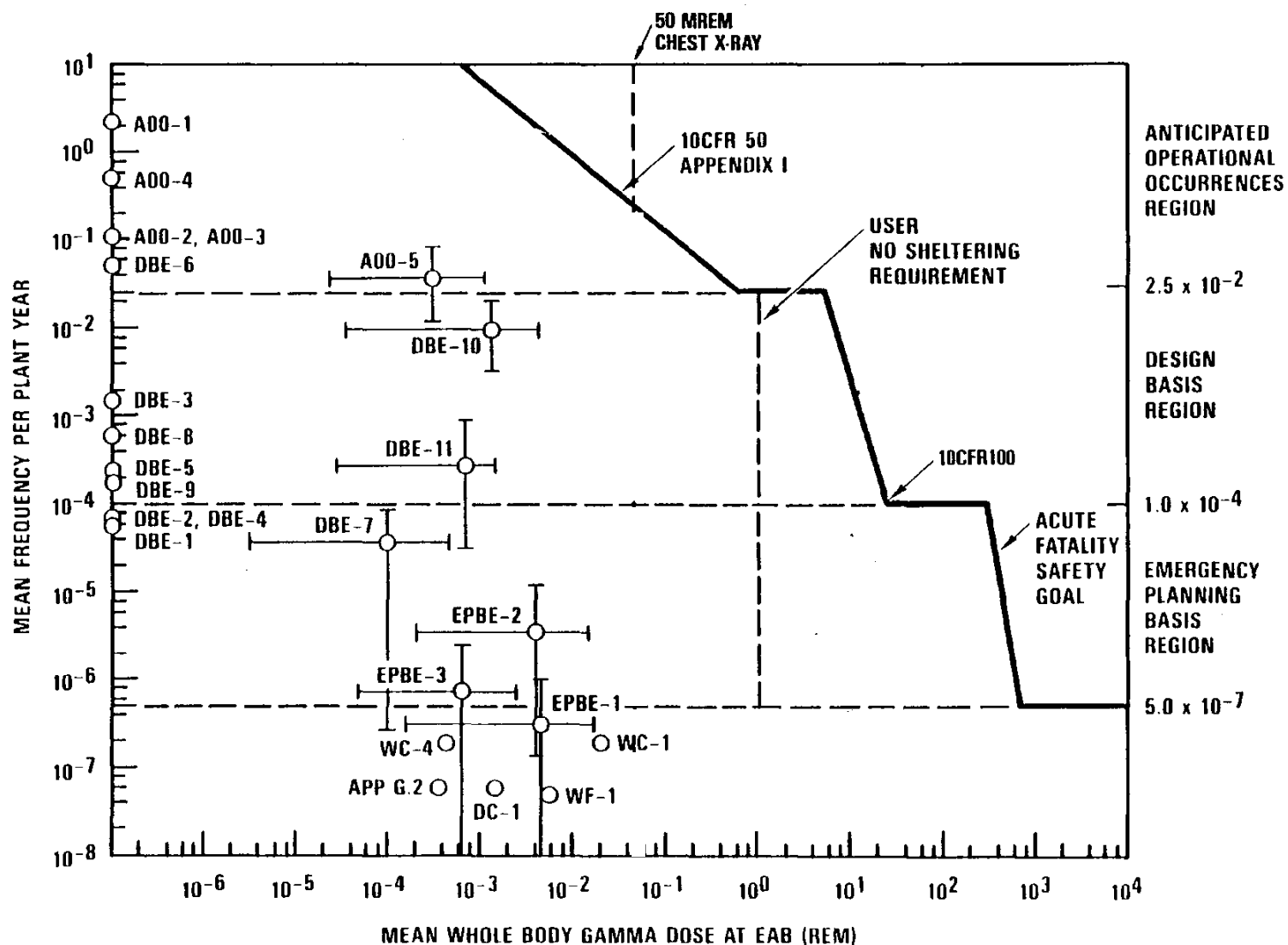
- Comparison Agreement
  - Formulation on the per plant year basis
  - Number of regions and terminology consistent with NGNP
  - Selected doses are in regulations and consistent with NGNP's
- Issues
  - Restrictive at high frequencies (US avg. background: 300 mrem from natural causes and 310 mrem from man-made per 2006 NCRP 160)
  - More restrictive at low frequencies than prompt QHO
  - **Design Basis Region extends to  $10^{-5}$ /plant year**
    - **$10^{-5}$ /plant year would limit siting for SSE and lead to more safety-related SSCs**
    - **Coverage below  $10^{-4}$ /plant year provided by DBAs that rely only on safety-related SSCs**
- Overarching concern is a stable, level playing field with other reactor types that are NGNP competitors
- NGNP intends to meet the selected TLRC consequence limits with large safety margins via the PAG design goal at the EAB

## ***Actions from May 16<sup>th</sup> Meeting***

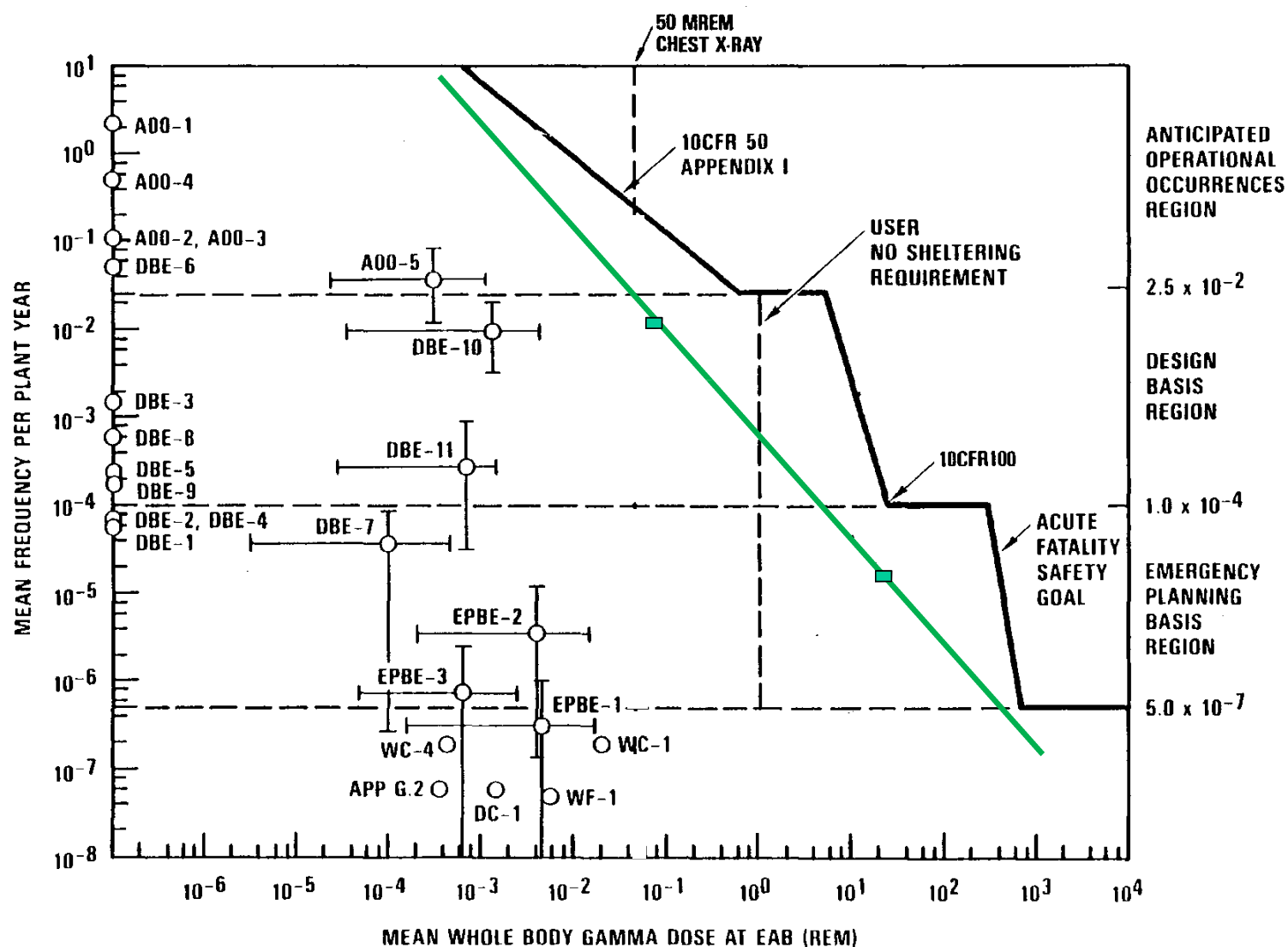
- **Action** - NGNP will plot the MHTGR events with uncertainties shown. NGNP will also indicate which of the DBEs and BDBEs are equivalent to the DBAs derived for evaluation in Chapter 15 with only safety related SSCs successfully responding.
- **Response** – Next slides

# MHTGR LBEs with Uncertainties vs. TLRC

(circa 1987)



## RAI Curve vs. MHTGR LBEs with Uncertainties

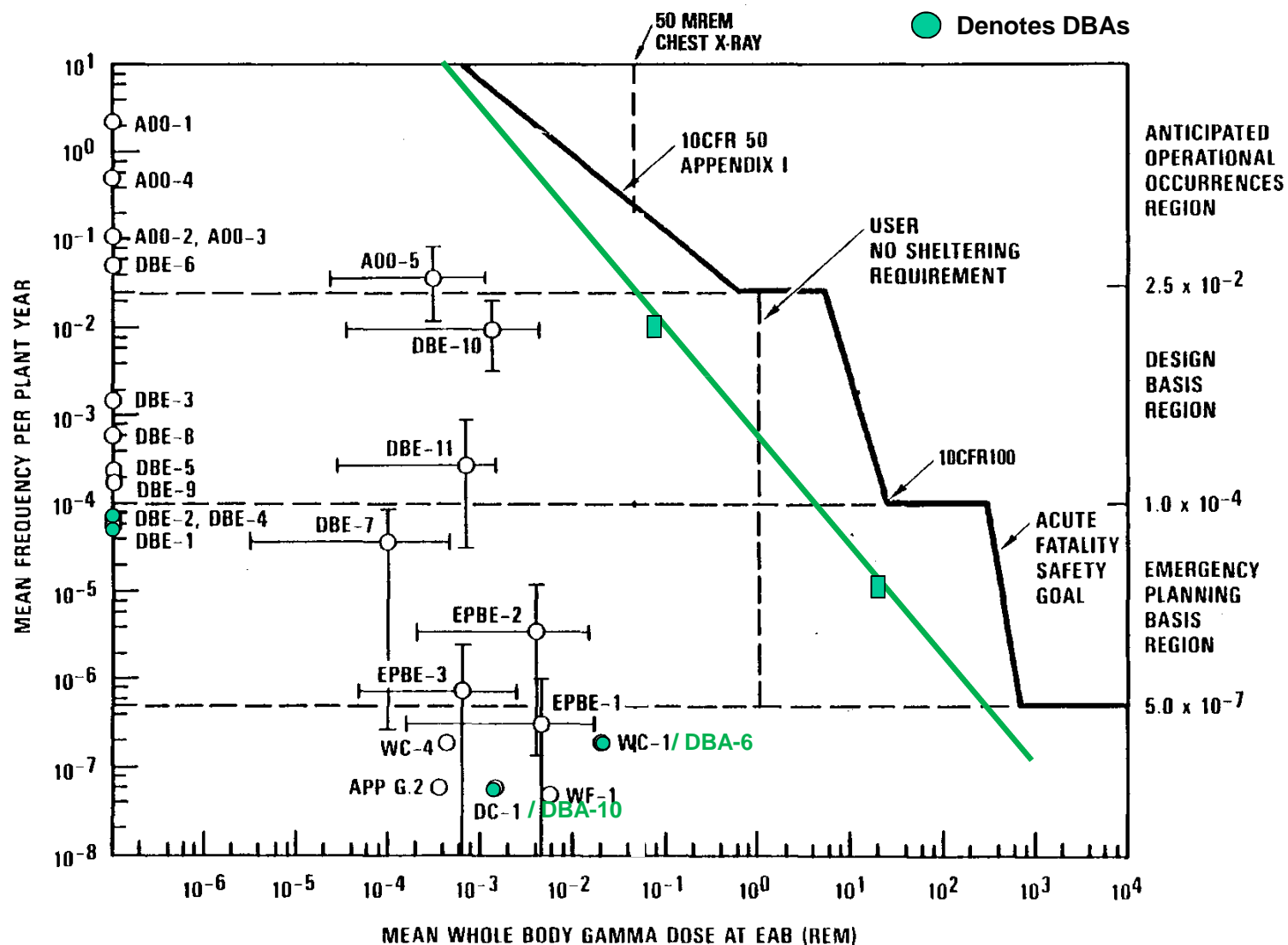


## ***MHTGR DBAs Derived from DBEs: 2 Same as DBEs Remaining 9 Collapse into 6 Lower Frequency Events***

<b>DBE</b>	<b>Design Basis Events</b>	<b>DBA</b>	<b>Design Basis Accidents</b>
<b>DBE-1</b>	<b>Loss of Main and Shutdown Forced Cooling</b>	<b>DBA-1</b>	<b>Loss of Main and Shutdown Forced Cooling</b>
DBE-2	Main Loop Transient w/o Control Rod Trip	DBA-2	Loss of Forced Cooling w/o Control Rod Trip
DBE-3	Control Rod Withdrawal w/o Main Loop Cooling	DBA-3	Control Rod Withdrawal with Loss of Forced Cooling
<b>DBE-4</b>	<b>Control Rod Withdrawal w/o Forced Cooling</b>	<b>DBA-4</b>	<b>Control Rod Withdrawal w/o Forced Cooling</b>
DBE-5	Earthquake	DBA-5	Earthquake with Loss of Forced Cooling
DBE-6	Moisture Inleakage	DBA-6 (WC-1)	Moisture Inleakage with SG Isolation with Loss of Forced Cooling
DBE-7	Moisture Inleakage w/o Forced Cooling	DBA-6	Moisture Inleakage with SG Isolation with Loss of Forced Cooling
DBE-8	Moisture Inleakage with Moisture Monitor Failure	DBA-6	Moisture Inleakage with SG Isolation with Loss of Forced Cooling
DBE-9	Moisture Inleakage with SG Dump Failure	DBA-6	Moisture Inleakage with SG Isolation with Loss of Forced Cooling
DBE-10	Moderate Primary Coolant Leak w/ Forced Cooling	DBA-10 (DC-1)	Moderate Primary Coolant Leak with Loss of Forced Cooling
DBE-11	Small Primary Coolant Leak w/o Forced Cooling	DBA-11	Small Primary Coolant Leak w/o Forced Cooling

# MHTGR DBAs on F-C Plot

3 Same as DBEs; 3 of 5 with Lower Frequencies Have Doses



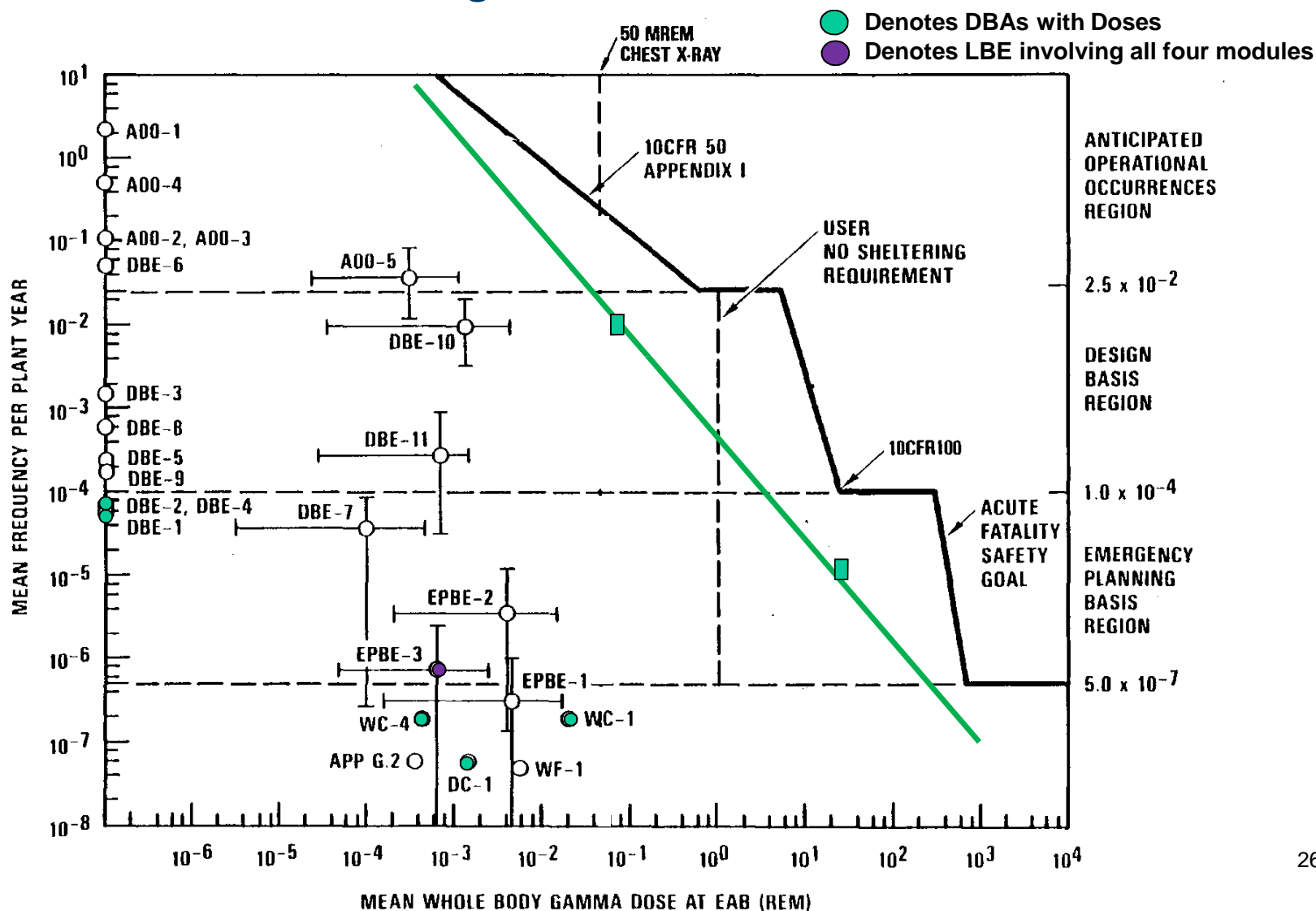


## ***Actions from May 16<sup>th</sup> Meeting*** *(continued)*

- **Action** – For the next meeting, NGNP will provide some examples of this approach for the MHTGR reference plant design of four reactor modules per plant with respect to the frequency-consequence (F-C) curve to illustrate the conservatism of the approach.
- **Response** – Next slide

# MHTGR LBE Impacting All Four Reactors

## EPBE 3 is EQ >SSE Leading to HPB Leaks/Breaks w/o Forced Cooling



## ***Actions from May 16<sup>th</sup> Meeting*** *(continued)*

- **Action** - NGNP should consider renaming this class of events (now called AOOs) to avoid future confusion. NRC recommended consulting NUREG-1860 for alternate terms such as frequent or routine events because it presents similar categories of plant events.
- **Response** – Terminology not yet decided. We note that RAI LBE-37 used the term AOO for the region above  $10^{-2}/\text{yr}$ .

## Summary

- An overall objective of this series of meetings is agreement with the placement of the TLRC on an F-C curve
  - Establish frequency ranges based on mean event sequence frequency for the LBE event categories
  - Endorse the “per plant-year” method for addressing risk at multi-reactor module plant sites
  - Agree on key terminology and naming conventions for event categories
  - **Reach agreement on the frequency cutoffs for the Design Basis Event (DBE) and Beyond Design Basis Event (BDBE) regions**
- Discussions and interactions have led to agreements on the first two sub-items and a better understanding of the similarities and differences with the three proposed F-C curves
- It is important that the selection of the DBE and BDBE cutoffs for the risk-informed process be taken in context with
  - the selection of the DBAs with their generally lower frequencies
  - the NGNP PAG design goal that will meet the TLRC consequence limits with large safety margins